APPENDIX 1 - ASSESSMENT OF LUMINESCENCE DATING

1.1 Luminescence dating

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Introduction

1.1.1 Age estimates have been derived for four sediment samples from the site of White Horse Stone, near Aylesford, Kent, using luminescence dating methods. The samples were collected by OAU staff, and submitted to the Luminescence Dating Laboratory, Research Laboratory for Archaeology and the History of Art, University of Oxford. Initial sample preparation was undertaken in 1999, and mineral separation and luminescence dating procedures were undertaken between July and October 2000. At the time that the samples were prepared and dated, no details of their relative stratigraphic positions had been provided, and the age estimates were conducted "blind".

1.1.2 An interesting suite of 4 preliminary dates has been measured. An interpretation based on the luminescence ages estimates and the stratigraphic relationships of the samples using a bayesian methodology appears to confirm the identification of an Allerød soil horizon. There is a degree of age inversion observed for the measured age estimates, discussed in further detail below, which suggests that some further investigation into the source of this phenomenon is warranted.

Methodology

1.1.3 With respect to sample preparation, these samples proved difficult to deal with in a number of ways. The preferred material for OSL dating within the Luminescence Dating Laboratory is fine to medium sand-sized quartz. While the samples did contain a certain amount of sand-sized material, only for sample X270 (ARC WHS98 309) was a sufficient quantity of quartz grains recovered for OSL dating. Following unsuccessful attempts for the remaining three samples to separate sand-sized quartz grains, the isolation of silt-sized quartz grains was attempted, using fluorosilic acid treatment. This methodology works well for quartz-rich silt samples, but for samples from a chalk bedrock provenance, previous results have been mixed in their degree of successful quartz isolation. For these samples, only negligible yields of silt-sized quartz grains were separated. In order to allow the determination of luminescence dates from these samples, fine-grained polymineral aliquots were prepared.

1.1.4 For sample X270 (ARC WHS98 309), a quartz OSL age based on the SAR (single aliquot regenerative-dose) protocol was measured. Owing to the low yield of quartz grains, only a brief concentrated HF acid treatment was used, and the natural alpha dose contribution was included in the age calculation.

1.1.5 For samples X267, X268 and X269 (ARC WHS98 306, 307 and 308 respectively), fine-grained polymineral age estimates were measured, using a post infrared blue OSL methodology. This allows the derivation of two semi-independent dates for each sample, using IRSL and OSL respectively. In each luminescence measurement step, an IRSL measurement directly precedes each OSL measurement. The IRSL signal is expected to be dominated by contributions from detrital feldspar grains, while the OSL signal is expected to have a significant contribution from quartz grains. Previous application of this methodology from samples from within late prehistoric ditch fill contexts suggests that the OSL signal can yield self-consistent age estimates, also consistent with the expected age of the dated context, while the

ISL age estimates tend to provide more scattered results, and have a tendency to overestimate the depositional age.

1.1.6 All OSL and IRSL measurements were made using Risø automated luminescence readers, using a natural and regenerated dose preheat of 220°C for 10s and a test dose preheat of 200°C for 10s. All luminescence emission signals were detected using Hoya U340 glass filters.

Sample details and results

1.1.7 Results of the age estimates derived are presented in Table 18.1, presented in approximate stratigraphic order.

Table 16.1: IRSL and OSL dating results from Profile G.

Lab Code	Field Code	Context	Sedimentary interpretation	IRSL age	OSL age
X267	306	4933	Solifluction deposit above soil	18,600±2,500	21,000±2,200
X269	308	4935	Allerød soil	21,200±1,800	16,800±1,700
X270	309	4935	Allerød soil	-	14,500±1,400
X268	307	4936	Solifluction deposit below soil	15,200±1,500	13,500±1,200

Discussion

1.1.8 Luminescence dating of sediments is a technique that determines the total environmental radiation that sample grains have been subject to since their last exposure to daylight. If deposition occurs with an insufficient daylight exposure event, luminescence dates may overestimate the true depositional age. Sediments such as aeolian sands or loess are usually found to be ubiquitously well bleached (exposed to light), while shallow marine and well-sorted fluvial deposits appear to be generally reliable materials with occasional slight age overestimates. The dating of sediments whose constituent grains may have been exposed to very little daylight, such as colluvial sediments, is subject to potential age overestimates, and some care must be taken in the interpretation of dating results for these materials. However, so long as there is no risk of age underestimation (due to other characteristics or sample behaviour), such dates may be interpreted as firm maximum age estimates. Where several samples are dated, it is extremely unlikely that each will suffer from the same degree of age overestimation, and hence the true age is often approached. The incorporation of stratigraphic relationships into a bayesian age model allows the optimum estimate of deposition for part or all of a suite of samples. This approach is well established for applications involving radiocarbon dating, and has been adopted for these luminescence dates.

1.1.9 Important to the reliability of this bayesian methodology is the assumption that the samples are not subject to effects, which may lead to age underestimation. While this is well established for quartz OSL signals, feldspar TL, IRSL and OSL signals may all suffer from anomalous fading, which can lead to age underestimates. This is the primary reason that dating based on quartz is generally preferred. In this suite of dates, the inclusion of one age estimate (X270) based on quartz, and the expectation that the post-IR blue OSL methodology preferentially isolates the quartz OSL signal is felt sufficient to justify this approach here. Therefore, it is the OSL dates that are discussed henceforth, while the IRSL are not considered useful in terms of providing reliable chronological control.

1.1.10 Two samples (X269 and X270) from a horizon tentatively identified as an Allerød soil, provided OSL age estimates which are consistent with each other within their associated uncertainties, though slightly older than expected for this period (Table

16.1). A sample from the layer immediately beneath this horizon gave a slightly younger age estimate, suggesting that this apparent overestimate was probably a result of incomplete bleaching. The age of this sample (X268) is consistent with deposition occurring immediately prior to the Allerød (Windermere Interstadial). It should be remembered that it is the age of the deposition of the soil parent material, rather than the period of soil formation, that luminescence dating is expected to provide for samples X269 and X270, within the soil horizon. The final OSL age estimate from solifluction deposits above the soil gives a significantly older age estimate of 21,000 ± 2,200 years. This would appear to represent sediment deposition without sufficient light exposure, perhaps catastrophically or very rapidly, possibly as a result of mass movement. The most likely period for this event would appear (from the other dates) to be the Younger Dryas cold period (or Loch Lomand Stadial). The LGM (last glacial maximum) age is interesting (perhaps representing aeolian input by loess-forming processes at peak LGM conditions, before later re-deposition), as is the implied contrast in depositional style between the solifluction deposit above and below the Allerød soil (perhaps the lower deposit was dominated by a series of minor slopewash events as opposed to a possible single mass movement event for the upper deposit), though it is not felt possible to conclude anything firmly on these matters without further investigation.

1.1.11 Table 16.2 provides a summary of the age estimate limits from the bayesian analysis of the OSL dates, performed using OxCal software, providing an age model for samples in a bounded stratigraphic sequence. This age model explicitly assumes that the ages are reliable, except for possible overestimation (resulting from incomplete zeroing at the time of deposition). The presence of such overestimation is implied by the observed age reversal, in particular for sample X267. To model this possible overestimation, the low age probability distribution was widened by a factor of five. This factor is somewhat arbitrary; however, a measure of the magnitude of the value required is provided by the maximum degree of age inversion observed. The value of this factor will affect the "agreement indices" quoted in Table 3. Values of > 60% are considered acceptable. However, it will make little difference to the central ranges of the age model results. These results appear to confirm the origin of the presumed Allerød soil; the age model results for the samples collected within the soil are 13,800 to 9,000 years before 2000AD for X 269 and 14,500 to 10,200 years for X270.

Table 16.2. Bayesian age model results at one standard deviation limits. An allowance for incomplete bleaching of all samples was made by multiplying the low age half gaussian distribution by a factor of 5.

Lab Code	Field Code	Context	Sediemtary interpretation	Age model range 1σ (years before 2000)	Agreement Index (%)
X267	306	4933	Solifluction deposit above soil	13,500-7,000	72.8
X269	308	4935	Allerød soil	13,800-9,000	104.2
X270	309	4935	Allerød soil	14,500-10,200	121.9
X268	307	4936	Solifluction deposit below soil	15,200-11,300	113.8

Potential

1.1.12 The application of a bayesian age model to a series of four OSL age estimates has allowed the confirmation of the assigned chronostratigraphy. By making sensible statistical allowance for the effects of incomplete bleaching, the age model can constrain the most likely age of samples forming a coherent sequence. The potential of such an approach is huge within a wide range of archaeological and environmental applications.

1.1.13 Further detailed research into the nature and magnitude of the overestimates for these samples is possible, but is unlikely to provide significantly better chronological resolution.

1.1.14 Given that the dating program has completed its objective in confirming the date of the lowest deposits within the dry valley as belonging to the Late Glacial phase of the Pleistocene, then there is no further potential. Other samples taken from elsewhere within the dry valley but from the same stratigraphic horizons, if processed and run, should be expected to replicate the above results.

Recommended further work

1.1.15 The results should be integrated with the environmental evidence from this sequenece.